The Impact of Changes to Surface Albedo on Radiative Forcing

PROBLEM

The energy entering, reflected, absorbed, and emitted by the earth are components of the earth's radiative budget. A budget that is out of balance can cause atmospheric temperature to increase or decrease, and eventually affect the earth's climate. Alterations to the budget are known as radiative forcing (RF). Modifications to surface albedo, a measure of the solar energy the Earth's surface reflects, have a direct impact on the relationship between the amount of energy reaching earth and the amount leaving it. Increasing the solar reflectivity of land surface can impact the amount of solar radiation bouncing back to space, thus altering the energy balance at the top-of-atmosphere. While many efforts have been made to assess the climate impacts of albedo, comparative analyses of different modeling approaches and results from existing studies are limited. This study compares results, quantifying the RF of albedo changes using different modeling approaches.

APPROACH

We first summarized the results from various studies on RF due to changes in surface albedo. We then normalized the RFs to a unit change in albedo of one percent and compared the normalized metrics across all available studies that report these quantities at the same spatial scale.

FINDINGS

The units of energy used to measure incoming and outgoing radiation are expressed in watts per square meter (W/m^2). Figure 1 shows a comparison of the RF from several studies in the literature normalized to every one percent increase in albedo. As shown in the figure, RFs calculated from different analytical and numerical models are comparable, ranging from -2.9 to -1.3 W/m^2 for a 0.01 increase in albedo; a negative number indicates a decrease in RF due to an increase in albedo, which would decrease the temperature in a given region.

The variation in results from the calculations comes from the assumptions and estimations used for solar insolation (short wave radiation) and atmospheric transmittance, both varying with location and cloud cover.

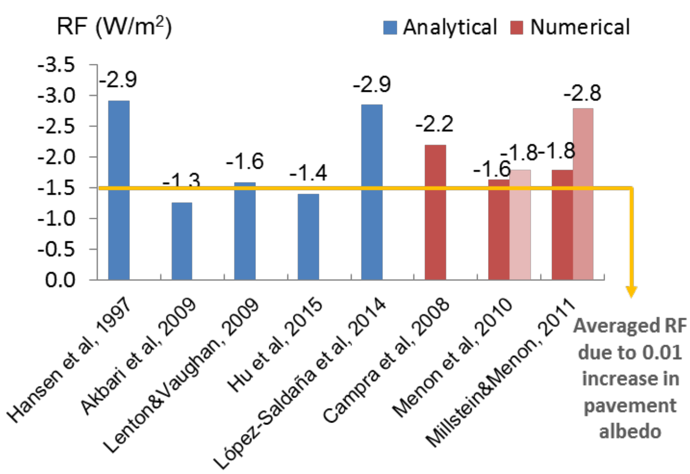

Figure 1: Comparison of normalized RFs due to 0.01 increase in albedo from analytical and numerical models The blue bars are studies that used analytical models to calculate RF*(1-5)*; red bars are studies using numerical models *(6-8)*. In *Menon et al, 2010*, dark red is for global land areas and light red is for the US only; in *Millstein & Menon, 2011,* dark red is annual average and light red is summer average

IMPACT

Results from the models and simulations analyzed here support the notion that an increase in surface albedo has a local cooling effect by increasing the total outgoing radiation. Most existing studies indicate a similar response: an increase in surface albedo yields a reduction in RF or an increase in outgoing radiation. The normalized results also reflected the sensitivities of the climate-related impacts to changes in surface albedo, and could be used to guide mitigation strategies. The RF values imply that a carbon dioxide offset would be expected if surface albedos were increased.

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